

STINFO COPY
United States Air Force
Research Laboratory



Pilot Harness Suspension Study

Benjamin C. Kuennen
John R. Buhrman

AIR FORCE RESEARCH LABORATORY

April 2004

Final Report for the Period September 2003 to April 2004

20050323 156

*Approved for public release; distribution
is unlimited.*

Human Effectiveness Directorate
Biosciences & Protection Division
Biomechanics Branch
2800 Q Street, Bldg 824, Rm 206
Wright-Patterson AFB OH 45433-7947

NOTICES

When US Government drawings, specifications, or other data are used for any purpose other than a definitely related Government procurement operation, the Government thereby incurs no responsibility nor any obligation whatsoever, and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data, is not to be regarded by implication or otherwise, as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

Please do not request copies of this report from the Air Force Research Laboratory. Additional copies may be purchased from:

National Technical Information Service
5285 Port Royal Road
Springfield, Virginia 22161

Federal Government agencies registered with the Defense Technical Information Center should direct requests for copies of this report to:

Defense Technical Information Center
8725 John J. Kingman Rd., Ste 0944
Ft. Belvoir VA 22060-6218

TECHNICAL REVIEW AND APPROVAL

AFRL-HE-WP-SR-2005-0001

The voluntary informed consent of the subjects used in this research was obtained as required by Air Force Instruction 40-402.

This report has been reviewed by the Office of Public Affairs (PA) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.

FOR THE DIRECTOR

//SIGNED//

MARK M. HOFFMAN
Deputy Chief, Biosciences and Protection Division
Air Force Research Laboratory

REPORT DOCUMENTATION PAGEForm Approved
OMB No. 074-0188

The public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing this collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.

PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.

1. REPORT DATE (DD-MMM-YYYY) April 2004		2. REPORT TYPE Final Report		3. DATES COVERED (From - To) September 2003 to April 2004	
4. TITLE AND SUBTITLE Pilot Harness Suspension Study				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER 62202F	
6. AUTHOR(S) Benjamin C. Kuennen, John R. Buhrman				5d. PROJECT NUMBER 7184	
				5e. TASK NUMBER 02	
				5f. WORKUNIT NUMBER 03	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Air Force Research Laboratory, Human Effectiveness Directorate Biosciences and Protection Division Biomechanics Branch Air Force Materiel Command Wright-Patterson AFB OH 45433-7947				8. PERFORMING ORGANIZATION REPORT NUMBER AFRL-HE-WP-SR-2005-0001	
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR / MONITOR'S ACRONYM AFRL-HEPA	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release; distribution is unlimited.					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT Test manikins are used extensively to collect ejection test data in situations not appropriate for humans, but the accuracy of the manikin data is directly dependent on how well the test set-up simulates the actual pre-ejection conditions experienced by the pilot. The objective of this program was to investigate the differences in harness tension among pilots and to compare these tensions to those typically used in a test manikin in order to provide validation for data collected during manikin impact tests. Four pilots and one Hybrid III 50th percentile manikin were lifted off the ground with a suspension hoist where a series of harness tension measurements were taken. The results demonstrated large individual differences among the human subjects and between the humans and the test manikin in the amount of harness slack generated by the lifting. Recommendations were made for setting the harness side adjustment index at level three during future mankin tests.					
15. SUBJECT TERMS Harness suspension, Harness tension, Harness adjustment, PCU-15/P harness					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT UU	18. NUMBER OF PAGES 12	19a. NAME OF RESPONSIBLE PERSON: John R. Buhrman
a. REPORT U	b. ABSTRACT U	c. THIS PAGE U			19b. TELEPHONE NUMBER (Include area code) (937) 255-3121

THIS PAGE LEFT BLANK INTENTIONALLY

PREFACE

This experimental effort was accomplished by the Biomechanics Branch (formerly the Biodynamics and Acceleration Branch) of the Human Effectiveness Directorate of the Air Force Research Laboratory at Wright-Patterson Air Force Base, Ohio. The effort was conducted at the request of ASC/ENFC in support of the Joint Strike Fighter (JSF) System Program Office (SPO). Technical support for the testing was provided by General Dynamics AIES under contract F41624-97-D-6004.

THIS PAGE LEFT BLANK INTENTIONALLY

TABLE OF CONTENTS

	<u>Page</u>
INTRODUCTION.....	1
METHODS.....	1
RESULTS.....	3
DISCUSSION.....	5
REFERENCES.....	6

LIST OF FIGURES

<u>Figure</u>	<u>Page</u>
1 PCU-16/P Harness.....	1
2 Frost Canopy Release and Link.....	2
3 Hybrid III Manikin in Suspension.....	2
4 Webbing Measurement Diagram.....	3

LIST OF TABLES

<u>Table</u>	<u>Page</u>
1 PCU-15/P Harness Measurement Data for Three Human Subjects.....	3
2 PCU-16/P Harness Measurement Data for Subject I1.....	4
3 PCU-15/P Harness Measurement Data for Hybrid III Manikin	4

INTRODUCTION

The use of manikins in ejection test environments has been in practice for a long time. In particular, they are used as replacements for human subjects in impact acceleration tests that are above the allowable pathophysiological tolerances for humans. However, the accuracy of the results of these tests is directly dependent upon how well the test set-up simulates the actual pre-ejection conditions experienced by the pilot.

Harness suspension studies done in the past have mainly focused on the physiological impact on the subject in the harness. These studies tested the tolerances of the subject while hanging in a harness for moderate lengths of time. Physiological parameters including blood pressure, extremity paresthesias (numbness/tingling), respiratory difficulty, nausea and location of strap pressure or pain have been thoroughly investigated. [1,2,3,4]

The current test program investigated variations of tension on the harness in relation to the subject. More specifically, it was to provide a clearer picture as to how much tension a harness would normally be under when used by a typical pilot. By recording data such as the adjustment points on the harness and how much slack is allowed by the harness with suspended subject, we can get a better idea of how to properly fit the harness to a test manikin.

METHODS

Four human male volunteers participated in this study. The subjects were Air Force pilots who were all on flying status and familiar with how the PCU-15/P and PCU-16/P harnesses fit, as shown in Figure 1. The PCU-15/P harness is generally used for subjects over 175 pounds and the PCU-16/P harness is for subjects under 175 lbs. Each subject's height and weight were measured prior to selecting the appropriate harness. Three of the human subjects along with the Hybrid III 50th percentile manikin were fitted with the PCU-15/P harness and one human subject was fitted with the PCU-16/P harness.



Figure 1. PCU-16/P Harness [5]

After the subject adjusted the harness to the desired fit, the harness side adjustment index number was recorded. This index number is located on the side adjustment strap spaced every two inches, starting with 1 as the loosest setting with the numbers increasing as the harness is tightened. The subject was then buckled to the Suspension Hoist parachute-style using Frost Canopy Release buckles (Figure 2). The subject was then lifted by a hoist to about six inches above the floor. The subject remained in the harness as webbing length measurements were taken (Figure 3). This process took about five minutes for each subject.

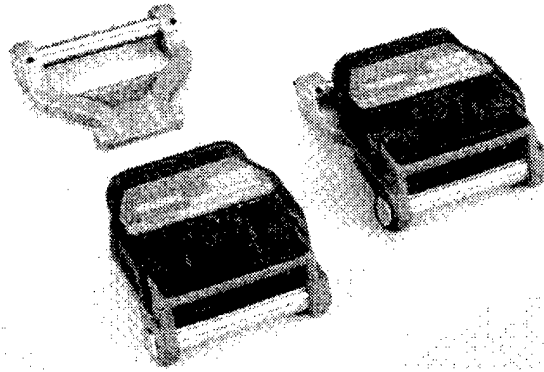


Figure 2. Frost Canopy Release and Link [6]

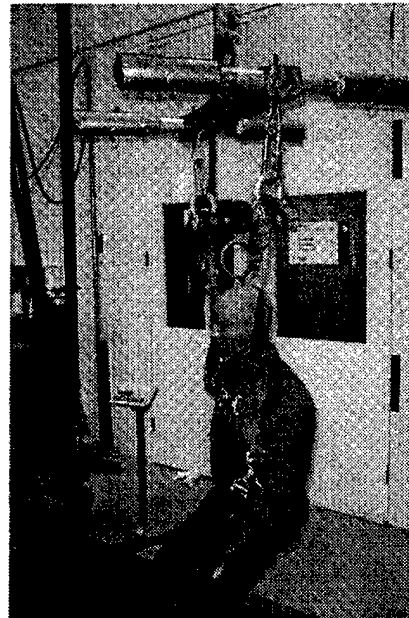


Figure 3. Hybrid III Manikin in Suspension

The measurements recorded were:

- A: The webbing length from the center of the buckle pin to a point tangent to the shoulder
- B: The webbing length from the center of the buckle pin to a point tangent to the chest
- α : The angle between A and B
- D: The distance between the center of the buckle pin to the nearest point on the chest

The value for C was calculated from A, B and α using the law of cosines formula $C^2 = A^2 + B^2 - 2AB\cos\alpha$. A diagram of the webbing length measurements is shown below (Figure 4).

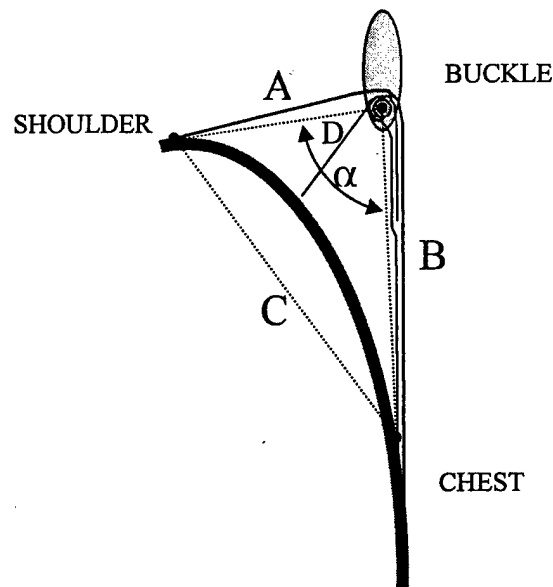


Figure 4. Webbing Measurement Diagram

RESULTS

The results from the harness measurements are listed in Tables 1-3. Table 1 lists the averages and standard deviations of upper harness webbing lengths taken from three human subjects wearing the PCU-15/P harness, and Table 2 lists the measurements of the only human subject wearing the PCU-16/P harness. Table 3 lists the measurements of the Hybrid III manikin wearing the PCU-15/P harness. All of the subjects had the side adjustment strap at index number three. Using the Grubb's Test for statistical outliers, it was determined that there were no outliers for the test results of this study.

Table 1. PCU-15/P Harness Measurement Data for Three Human Subjects

	Height (in)	Weight (lbs)	A Left (cm)	A RT (cm)	B Left (cm)	B RT (cm)	C Left (cm)	C RT (cm)	D Left (cm)	D RT (cm)	α Left (Deg)	α RT (Deg)
S1	71.5	199	15.2	15.2	6.4	7.6	17.5	16.8	3.2	3.8	99.7	88.1
B1	73.5	196	12.0	13.0	8.0	9.0	14.5	14.5	6.0	5.0	91.0	80.1
M1	68	184	15.5	15.1	13.0	13.5	21.6	21.3	8.3	7.4	98.2	96.0
AVE	71.0	193.0	14.2	14.4	9.1	10.0	17.9	17.5	5.8	5.4	96.3	88.1
ST DEV	2.8	7.9	1.9	1.2	3.4	3.1	3.6	3.5	2.6	1.8	4.7	8.0

Table 2. PCU-16/P Harness Measurement Data for Subject I1

	Height (in)	Weight (lbs)	A Left (cm)	A RT (cm)	B Left (cm)	B RT (cm)	C Left (cm)	C RT (cm)	D Left (cm)	D RT (cm)	α Left (Deg)	α RT (Deg)
I1	69	167	12.5	12.0	8.8	8.0	13.3	11.7	6.9	7.4	68.6	75.0

Table 3. PCU-15/P Harness Measurement Data for Hybrid III Manikin

	Height (in)	Weight (lbs)	A Left (cm)	A RT (cm)	B Left (cm)	B RT (cm)	C Left (cm)	C RT (cm)	D Left (cm)	D RT (cm)	α Left (Deg)	α RT (Deg)
HB3	67	157	15.0	16.0	15.0	15.0	19.1	20.5	9.5	7.6	79.1	82.5

It was observed that one of the PCU-15/P subjects, B1, and the PCU-16/P subject, I1, had the harness raised nearly off both shoulders, while the others had the harness remain in contact with the shoulders. This is likely due to improper adjustment of the side adjustment strap, which controls the torso length of the harness. Since this study was to test how pilots actually wear the harness, no instructions were given and no adjustment was made to the manner in which any subject put on their harness.

There were large individual differences among the human subjects in the harness webbing lengths measured during the lifting, due in part to apparent adjustment inaccuracies created by the subjects. It is assumed that greater webbing lengths would normally correspond to either less slack in the initial harness adjustment stage or greater tension on the straps during the lifting. In general, the webbing length was less for the smaller subject, who was using a PCU-16/P harness, compared to the mean of the three larger subjects who all used the PCU-15/P harness. This was probably due in part to the slightly lower tension on the harness straps resulting from this subject's lighter weight as well as the smaller dimensions of the PCU-16/P harness. However, the webbing measurements for the small subject were all within two standard deviations of the mean for the large subjects, and two of the measured webbing lengths (B and D) were actually greater than those of one of the large subjects. This implies that the amount of slack in the initial harness fit as well as the subjects' body dimensions may also have been significant factors. The angle (α) between the shoulder webbing (A) and the chest webbing (B) lengths, while not varying very much among the three larger subjects wearing the PCU-15/P, was about 20% less for the smaller subject wearing the PCU-16/P. This also may have been due in part to the smaller dimensions of the PCU-16/P harness.

All measured webbing lengths (A, B, and D) were unexpectedly greater for the Hybrid III manikin than for any of the human subjects. Since the manikin was lighter than any of the human subjects, it would have been expected to generate less tension during the lifts with correspondingly smaller webbing lengths. The greater webbing lengths must have instead been due either to more slack created by less tightening in the initial adjustment of the harness or to lessening of tension when the manikin was hoisted and the harness pushed into the manikin's soft skin. However, it is unclear why the angle α measured with the manikin was smaller than α measured with the human subjects.

DISCUSSION

Having each subject adjust the harness himself possibly created an unknown in this study. None of the subjects appeared to make adequate adjustments to the side adjustment strap. It is unclear whether this was merely an oversight by the subject or if the individual does indeed prefer to have the strap adjusted at that particular setting. This study was carried forward under the assumption that the adjustments would be a true representation of how the pilot would wear the harness, an assumption that may or may not have turned out to be true. However, based on the assumption, it would be recommended to have the manikin strapped in at an index level of three. A more comprehensive study of this adjustment may be necessary to determine a "true" average index number of pilots and flight crew.

A likely reason for the inaccurate adjustments is that the subjects put the harness on and adjusted it while standing. The harness is really designed for pilots strapping into an ejection seat to adjust and clip the buckles while *sitting* in the seat of the aircraft, making the harness fit much tighter. This creates a different feel to the harness than when it is put on while standing, which is relatively loose for comfort. Also, the side index numbers have a correlation to the torso length, a measurement not taken in this study. Again, since this study was going by how the wearer feels in the harness, this was not measured to gain accuracy in fitting.

The only way to show if these results have any effect on testing would be to run two sets of manikin ejection seat tests. One test would be carried out in a "business as usual" manner as it has in the past. The other set of tests would have the harness adjusted to the manikin in the manner described in this report. After running both sets of tests, statistical comparison of the manikin reactions would be able to determine if there is any difference between the two. It might also be worthwhile to adjust the side adjustment strap to various positions to determine if there are any statistical differences in this as well.

REFERENCES

1. Hallel, T. and Naggan, L., "Parachuting Injuries: A Retrospective Study of 83,178 Jumps," Journal of Trauma, 15(1):14-19, 1975.
2. Hearon, B.F. and Brinkley, J.W., Fall Arrest and Post Fall Suspension: Literature Review and Directions for Further Research, AFAMRL-TR-84-021, Air Force Aerospace Medical Research Laboratory, Wright-Patterson AFB OH, April, 1984.
3. Nelson, B.A., "Climbing Harness: How Long Can You Hang In Your Harness?" in Off Belay, pp 10-12, August 1979.
4. Seaworth J., "Evaluation of Fall Protection Equipment by Prolonged Motionless Suspension of Volunteers," SAFE Journal 17(2):46-53, 1987.
5. <http://lifesupportintl.com/PCU-16P.htm>
6. <http://www.capewell.com>